

IMPROVED CARBON BRAKE  
WEAR FOR AIRCRAFT

This invention relates to a method and means for  
5 increasing the life of carbon aircraft brakes. More  
particularly, this invention relates to the controlled  
application of braking pressure to only selected brakes  
during low speed ground travel.

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BACKGROUND

Modern aircraft which are designed to carry large  
passenger or cargo payloads are often provided with carbon  
brakes on each of the wing or body mounted wheels. The  
15 nose wheel is typically not braked. Carbon brakes are  
preferred because of their light weight and performance  
characteristics and generally comprise a piston housing  
and parts, a torque plate and a carbon heat sink stack.  
This stack contains all the friction surfaces which, when  
20 compressed, cause the wheel to decrease its speed. The  
stack comprises a pressure plate, rotor disks, stator  
disks and backing plate. Carbon composite rotors are  
connected to the wheel through the rotor drive keys and  
turn with the wheel. Carbon composite stators, pressure  
25 plates and backing plate are connected to the torque tube  
and do not turn. Braking friction is caused when the  
rotors are compressed against the stators.

While carbon brakes are preferred for weight and  
30 performance reasons over steel brakes, the cost of  
replacing the stack divided by the number of landing  
cycles between replacements is much higher than for steel  
brakes.

## PATENT

Aircraft brake control systems are designed with separate pedal controls for the left and right brakes. When one of the brake pedals is depressed, all the brakes on that side of the aircraft are commanded to apply  
5 simultaneously and equally. By applying all brakes equally, the heat energy absorbed by each individual brake is minimized. For steel brakes, brake life is largely determined by the total amount of energy absorbed by each brake and is largely unaffected by the number of brake  
10 applications that accumulate that energy. Hence, brake control systems that apply all brakes simultaneously and equally provide economic operation of steel brakes and minimize exposure to overheating of any individual brake. However, direct application of this method to carbon  
15 brakes does not extend and may significantly shorten their lives. Accordingly, this invention provides a novel method and means to extend the life of carbon brakes and substantially reduce their operating cost.

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### BRIEF SUMMARY

In accordance with the invention carbon brake life is significantly extended by decreasing the number of brake applications during each landing cycle. More  
25 particularly, brake wear has been found to correlate significantly with the number of brake applications and to not be significantly affected by the energy absorbed during each. By far the largest number of brake applications occur during ordinary taxiing, so in  
30 preferred embodiments of this invention, only some of the brakes are applied in response to brake applications under ordinary taxiing conditions. An alternating wheel braking

pattern is established to minimize brake wear at each  
braked wheel and yet to promote even distribution of  
absorbed energy among all the brakes. This, in turn,  
prevents overheating of any individual brake. The  
5 extended brake-wear system is activated only when aircraft  
ground speed and brake application pressures are typical  
of taxi operations. Preferably, aircraft speed and  
hydraulic pressure are sensed so that brakes at all wheels  
will be operative in critical braking situations such as  
10 landing, parking, or emergency stopping.

The invention will be better understood in terms of  
the Figures and detailed description which follow.

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#### DETAILED DESCRIPTION

Figure 1 is a simplified schematic of a subsystem for  
20 aircraft brakes which alternately disables one of two  
brakes in order to limit the number of brake applications  
and extend carbon brake life.

Figure 2 is a schematic view of a sixteen wheel and  
25 brake landing gear configuration for a wide bodied  
aircraft showing a brake disable circuit which would be  
activated under low braking pressure and aircraft speed  
conditions representative of taxi braking to disable half  
the brakes and thereby extend brake life.

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For carbon brakes, the landings to wear-out ratio is  
strongly dependent on the number of brake applications

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rather than the energy absorbed by a brake during each application. For commercial passenger aircraft, the brakes may be applied an average of twenty times per landing cycle. The brakes are generally applied during  
5 landing absorbing several million foot-pounds for heavy wide-bodied aircraft and once to stop the wheels from spinning before they are retracted after take-off. Both of these are "high speed" brake applications, and are typically at moderate hydraulic pressures less than about  
10 1500 psi hydraulic pressure. The balance of the brake applications are "taxi snubs" for steering or low speed braking. They create hydraulic brake fluid pressures generally less than about 1500 psi and absorb about 0.5 MFP average per snub for wide-bodied aircraft. These taxi  
15 snubs account for a significant amount of brake energy temperature buildup, and for carbon brakes, most of the wear since carbon brake wear is dependent on the number of brake applications. Occasionally, "emergency" brake applications may be made at higher pressures (up to 3000  
20 psi hydraulic fluid pressure), but such emergency braking is an insignificant wear factor.

Conventional brake wear control systems provide for applying all brakes equally, gently, and simultaneously  
25 during normal taxi braking. In accordance with a preferred embodiment of this invention, the life of carbon brakes is extended by minimizing the number of brake applications while distributing the heat energy absorbed substantially equally among all the brakes. This is  
30 accomplished by alternately applying only a selected number of brakes rather than all the brakes during each normal taxi braking operation.

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A simplified example of a preferred embodiment of this invention is shown schematically in Figure 1. A left wheel 2 and right wheel 4 are on the same side of an airplane and are actuated by the one of the two brake pedals in the cockpit. Wheel 2 has a carbon brake 6 and right wheel 4 a carbon brake 8. In this embodiment, the antiskid control system 10 is integral to the brake disable system. Left and right wheel speed sensors 12 and 14, electronically measure wheel speeds and input the signals generated to the antiskid control circuit 10. Signals from antiskid control circuit 10 are outputted through diodes 16 and 18 to left and right hydraulic antiskid valves 20 and 22. The signals from wheel speed sensors 12 and 14 are integrated by antiskid control circuit 10 and outputted to brake disable control circuit 24.

Brake metering valve 26 which is responsive to a call for braking from the cockpit is located in brake hydraulic line 28. The static line pressure is low, pressure during taxi snubs is higher, and pressure during parking and emergency braking is relatively higher still. This pressure is measured at metered brake pressure sensor 30. The signal from sensor 30 is inputted to brake disable control circuit 24.

The system works in accordance with the invention as follows. The speeds of wheels 2 and 4 are sensed through sensors 12 and 14 and processed in antiskid control circuit 10 to determine aircraft speed. That aircraft speed signal is inputted to brake disable circuit 24. The

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desired intensity of braking action is sensed by the metered brake pressure sensor 30 and is also inputted to brake disable circuit 24. Inside brake disable control circuit 24, the metered pressure signal is compared  
5 against a first predetermined value, 100 psi for example, to detect when a brake application has been commanded. At the moment at which a brake application is detected, a comparison is made between the aircraft speed signal and a predetermined value for aircraft speed in brake release  
10 logic circuit 32. If the speed is higher than the predetermined value, 40 mph, for example, then brake disablement is not <sup>enabled</sup> ~~disabled~~. Subsequently, comparison is continuously made inside brake release logic 32 between the metered pressure signal value and a second  
15 predetermined value. If the pressure is greater than the second predetermined value, greater than 1500 psi, for example, then the brake disable control circuit 24 does not disable any brakes. That is, if heavy braking intensity is called for, all the brakes are applied. If  
20 and only if aircraft speed at the time of brake application and metered brake pressure are lower than their predetermined maximum values will brake release logic circuit 42 be activated.

25 As indicated by bipolar knife switch 36, only one of the two antiskid valves 20 and 22 will be commanded to release its respective brake through left diode 38 or right diode 40 when brake release logic 32 triggers. Brake select logic circuit 42 remembers which brake was  
30 last disabled and switches switch 36 when a new brake application has been detected by brake disable circuit 24.

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Brake disable logic 24 responds to both the metered pressure signal and the aircraft speed signal at the time of brake application. Thereafter, logic circuit 24  
5 responds only to the metered pressure signal from sensor 30 until the metered brake pressure returns to the no-braking system pressure. This ensures that following a high speed brake application, such as a landing, the brake release command will not be produced, and half the brakes  
10 will not be released, as the aircraft decelerates through the brake disable speed threshold. The disable signal would then only be produced at low speed after the brakes were released, then reapplied.

15 If an emergency stop, i.e., high metered pressure is sensed by brake disable circuit 24, then brake release logic 32 removes the brake release command so that both brakes 6 and 8 are applied, thus insuring full aircraft braking capability when it is needed. Similarly, if a  
20 higher speed stop, such as a landing stop or rejected take off, is sensed by brake disable circuit 24 from the aircraft speed signal, then the brake release logic 32 removes the brake release command so that both brakes 6 and 8 may share the braking energy, preventing overheating  
25 of an individual brake or brakes.

While the desired braking intensity has been described in terms of metered braking pressure, other input to the brake disable circuit providing like information would be  
30 equally useful. For example, the acceleration and throw of the brake pedal in the cockpit could be monitored or the rate of brake temperature increase. Similarly, input

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1 other than aircraft speed such as wheel speed or aircraft  
2 ground speed measured independently of the wheel speed  
3 could be inputted to the brake disable circuit. Such  
4 alternatives will be apparent to those skilled in the art.

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6 The invention has been described specifically in  
7 Figure 1 in terms of a brake pair on one side of an  
8 aircraft. However, systems in accordance with this  
9 invention for aircraft with other numbers and arrangements  
10 of carbon braked wheels could be readily adapted by  
11 persons skilled in the art. For example, Figure 2 shows  
12 the wheel configuration for a wide-bodied Boeing 747-400™  
13 series aircraft equipped with a carbon brake on each main  
14 gear wheel. The nose wheel which is not braked is not  
15 shown.

16  
17 Referring to Figure 2, there are four four-wheel  
18 trucks located under the left wing 44, left body 46, right  
19 body 48 and right wing 50 of an aircraft. Using truck 44  
20 as an example, wheels 52 and 54 on one side, and 56 and 58  
21 on the other side of a four-wheel axle frame 60 each  
22 provide input to a brake disable circuit 62 like that  
23 described in Figure 1. A metered brake pressure signal  
24 would also be provided to each like brake disable  
25 circuit. Thus, when both the aircraft speed at time of  
26 brake application and metered brake pressure are below  
27 target values, half of the sixteen brakes would be  
28 disabled. For example, brakes on wheels 52 and 54 on the  
29 left side of the truck 60 would be alternately disabled  
30 during successive brake applications as would the brakes  
31 on wheels 56 and 58.

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## PATENT

Since Carbon brake wear is a function of the number of applications, and since the vast majority of brake applications occur during taxiing, the life of carbon brakes is significantly improved by practicing this invention. For example, if half the brakes are applied during each taxi brake application, brake wear life could nearly double. The life of carbon brakes might be proportionately extended even further by disabling even more than half the brakes during each braking cycle. System logic insures maximum braking capability during emergency braking, i.e., high pressure, conditions. Overheating of individual brakes is prevented because system logic alternates between brakes to share the braking energy among all the brakes.

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Other system refinements such as redundant metered pressure sensors could be added to improve failure mode performance. Also, means could be provided to smooth brake pedal control responsiveness in the cockpit between partial brake and full brake transitions. That is, the back pressure on the brake pedal could be adjusted so that equal pedal depression results in equal braking responsiveness irrespective of how many brakes are being disabled at a given time. Brake temperature could also be considered in the brake disabling algorithm to prevent disablement if some brakes are too hot from previous brake applications.

While the invention has been described in terms of specific embodiments thereof, other forms may be readily adapted by one skilled in the art. Accordingly, the scope of the invention is to be limited only in accordance with the following claims.